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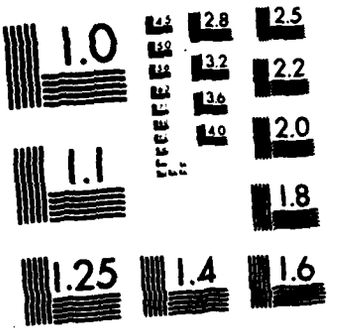

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20. Abstract

This report describes the construction of an advanced, high-resolution, photofragmentation-translation spectrometer. The major features of the machine are as follows. It is capable of mesuring the differential, cross-section and translational-energy distributions of collisionless, photo-chemical events. It has a rotating, molecular-beam source and a fixed detector. This allows extreme temperatures in the bakeout process which will give very low background in the detector. The detector is an advanced design, electron-impact ionization, quadrupole mass-spectrometer. The pumping system uses cryopumping and turbomolecular pumps. This will increase the pumping speed for hydrocarbons and allow the low backround detection of hydrocarbon masses.

The purpose of this machine is to measure the product translational-energy distributions of photochemical processes, especially the photo-decomposition of rocket fuel prototypes, so called "energetic materials". The low vapor pressure of these substances requires an efficient detector with a low background at hydrocarbon masses.

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CROSSED MOLCULAR BEAM STUDY OF THE REACTIONS OF OXYGEN AND FLUORINE ATOMS

Prepared for the
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THE CONSTRUCTION OF AN ADVANCED HIGH RESOLUTION PHOTOFRAGMENTATION TRANSLATION SPECTROMETER

INTRODUCTION

The importance of the translational energy release in a photochemical reaction has prompted the construction of an advanced, high, resolution photofragmentation translation spectrometer. During the last year significant progress has been made in the design and construction of the new instrument. The purpose of this report is to describe the work accomplished in the last year and the current state of the project.

Over the course of the last year the design for the entire instrument has been completed. Technical drawings have been made and submitted to the mechanical shops. The machine consists of a cubical main chamber and a rotating molecular beam source. The source provides differential pumping for the rotating molecular beam without resorting to the clumsiness of a rotating pumping system. The molecular beam passes into the interaction chamber through a defining slit and a liquid helium cooled cold plate. The purpose of the liquid helium cooled cold plate near the interaction region is to provide a much lower background in the detector and will be described later. A port is provided for a horizontal laser beam to pass along the axis of rotation of the source. A removeable, triply, differ- entially, pumped, ultra-high vaccuum, quadrupole, mass-spectrometric detector samples the scattered photo-products at a variable angle with respect to the initial direction of the molecular beam. This allows the measurement of the angular distributions of the process being studied. The flight length of the machine has been increased to forty centimeters for increased resolution in

the measurement of the translational energy distribution. Special care has been taken in the design of the detector in order to increase its detection efficiency and lower the background gas densities.

The mechanical shop has thus far completed the main chamber, the rotating source and most of the detector. The ionization chamber has albo been completed and awaits alignment and final cleaning. The entire main chamber and rotating source have been assembled with vaccuum pumps and "pump tested". The precision alignment of the rotating source has been completed and a fluorescence detector is ready to begin testing of the molecular beam source. The first two regions of differential pumping for the detector have been completed, "pump tested" and precision aligned. The quadrupole holder, and the ion counter have been completed and await final testing.

The following sections describe the above in further detail.

MAIN CHAMBER

The main chamber was designed, constructed and assembled within the last year. It is roughly a three foot cubic chamber divided into two regions by a vertical, stainless steel partition plate which has a large (25 in.) hole cut in it. The two regions are pumped separately by diffusion pumps. The main interaction region, where the molecular and laser beams cross is being pumped by an Edwards "Diffstack" diffusion pump. This gives us a very clean environment for the laser optics which will be focusing high energy laser beams. The rotating source fits into the 25 in. hole and separates the source region from the main interaction region. In this way

the source region is pumped separately from the interaction region without having to rotate the pumping system. There is a very large (30 in.) hole cut into the front wall of the chamber. This provides the precision aligned surface on which the rotating source is seated and rotates along. There is precision cut rectangular hole (21 in. x 17 in.) in the side wall of the chamber which is for the precision alignment of the detector. All of the highly critical, precision work done by the machine shops has been checked directly in the laboratory. The chamber has been assembled with all of its pumping system and "pump tested" down to a pressure of 2×10^{-7} torr.

ROTATING MOLECULAR BEAM SOURCE

The rotating, molecular-beam source has been designed, fabricated, assembled and aligned in the last year. The source chamber and the region used to differentially pump the beam before it enters the main interaction chamber is mounted to two large stainless steel plates, one on each end. One of these plates is the partition plate and the other is the rotating plate which seats into the precision surface in the main chamber. Differential pumping is accomplished by mounting a small turbomolecular pump on the rotating seating plate. This pump pumps on the differential region and the exhaust of the pump is fed back into the source region. The turbo-pump acts simply as a compressor between the two regions. Since the gas load on the differential region is on the order of 1% of that on the source region there is nothing wrong with emptying the exhaust into the source region. The seating plate is precision machined to fit into the main chamber. The alignment of the source was checked directly in the laboratory to insure

that the source maintains its critically aligned position at all angles of rotation. The source has also been "pump tested" down to 2×10^{-7} torr. A liquid-helium cooled collimation-slit attaches on the output of the molecular-beam source. The beam passes through the slit and continues on to the interaction volume through a liquid helium cooled cold plate. The reason for the cold plate is as follows. The detector is precision aligned so that its viewing window always overlaps the crossing volume of the laser and molecular beams. Whatever happens to be behind the crossing volume is also viewed by the detector. In past machines this has been the wall separating the differential pumping region from the main interaction chamber. That is, a room temperature piece of stainless steel. With the liquid-helium cooled collimation-slit the detector will always be viewing an extremely cold piece of metal. As a result, the contribution to the background which is due to the desorption of gas and gaseous molecules scattered from this surface will be greatly reduced. This has yet to be tested although it has been constructed.

LASER SYSTEMS

Two types of experiments are planned. One involves single UV photon photodissociation, while the other would use multiple infrared photon dissociation. We already have a very high power, high repitition rate I.R. laser for the multiple photon excitation. We are in the process of purchasing an excimer pumped dye laser system for the UV experiments. We are attempting to acquire a pulsed, excimer-pumped, tunable, dye laser system capable of 0.1 cm^{-1} resolution in its normal mode and 0.02 cm^{-1}

resolution with an intracavity etalon. This will allow single rovibronic state excitation in excited electonic states of organic molecules. We can also use the excimer laser by itself as a source of intense single frequency radiation. The future acquisition of a vacuum UV laser and a picosecond laser will expand the scope even further.

FLUORESCENCE DETECTOR

A simple photomultiplier fluorescence detector has been constructed and assembled in the last year. This will be used to monitor the fluorescence from photoexcited molecules to confirm that absorption is occuring during the experiment. Time resolved fluorescence can also be measured with a gated integrator data collection system we have purchased. This detector has been tested separately from the molecular-beam machine, but has as yet not been tested with it.

TIME OF FLIGHT MASS SPECTROMETRIC DETECTOR

The time of flight mass spectrometric detector consists of the following components: two regions of differential pumping between the main interaction region and the ionization region of the mass spectrometer, a liquid-nitrogen cooled, ionization region and a separately pumped, mass spectrometer region for the quadrupole mass filter and the Daily ion counter. All of the four regions are pumped with very clean turbomolecular pumps in order to increase the pumping speed for hydrocarbons which are notoriously badly pumped by ion pumps, used in past designs. The ionization region will be pumped by a magnetically suspended turbomolecular pump, where

the bearing of the pump is provided by a magnetic field. This allows the elimination of hydrocarbon based lubrication fluids, used in past designs of these pumps. This further lowers the hydrocarbon background. The neutral molecules will be ionized in a high efficiency (10^{-4}) Brinks type ionizer. This ionizer is directly designed after our past design and will work identically. The ions are collected by focussing optics and injected into the quadrupole mass filter. The mass selected ion is then detected by a Daily type ion counter. The entire detector is mounted on ball-bushings which roll smoothly along case hardened stainless steel shafts. This allows the movement of the entire detector while the pumps are running. This will mean that the detector will be completely removable from the main chamber for bakeout, allowing very high bakeout temperatures and consequent reduced background.

So far, the shop has completed the differential pumping regions, the ion counter and the quadrupole holder. The table for the detector has been assembled with the stainless steel shafts and ball-bushing supported stands. The differential pumping regions have been precision aligned and assembled once for "pump testing". The ionization region still requires final precision alignment to the main chamber.

SLOTTED CHOPPING WHEEL

We have built and assembled a slotted chopper wheel assembly which will be use to chop the continuously running molecular-beam so that we can measure the primary beam velocity. This has been tested and works fine.

FUTURE PLANS

In the future we would like to finish the assembly and testing of the high resolution photofragmentation translation spectrometer. We will then use this instrument to look at the mechanism and dynamics of primary thermal and photodissociation of polyatomic molecules, especially those low vapor pressure energetic materials. Among our other planned experiments are: The dependence on vibrational motion of the photodecomposition of organic molecules which must decay through internal conversion to the quasicontinuum of the ground electronic state in a molecule originally excited to the lower vibrational levels of the first excited singlet state; the dynamic of concerted molecular dissociation through a cyclic transition state.